Flow Measurement in Liquids and Gases

(Oil and Gas Perspective)

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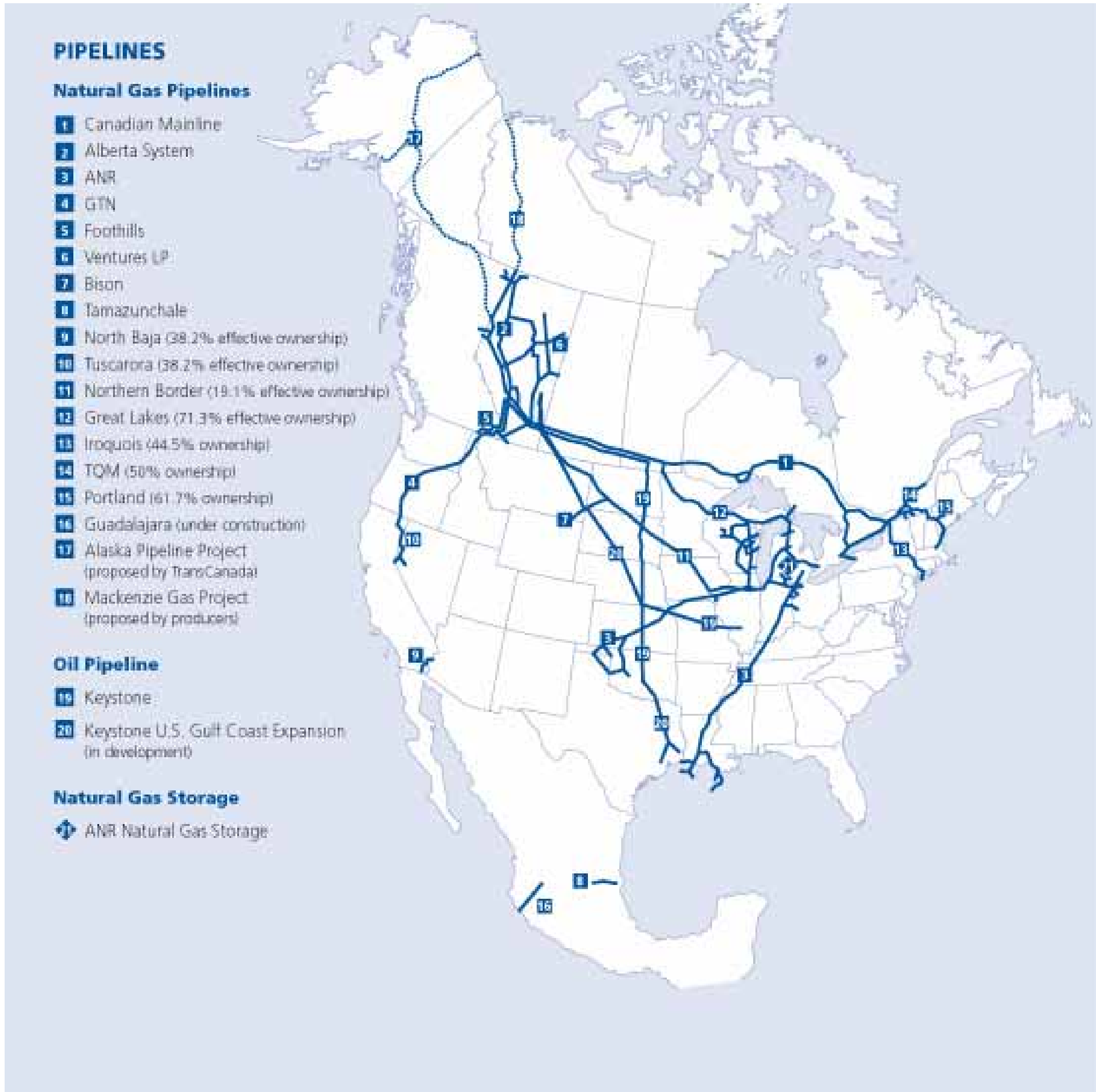
Agenda:

1. Production statistics
2. Legal requirements and flow measurement standards
3. Industry association
4. Measurement uncertainty
5. Types of meters
6. Metering lifecycle cost analysis
7. Questions

Production Statistics



Production Statistics

In 2012, Alberta's total marketable natural gas production, including coalbed methane, was 3.7 trillion (1×10^{12}) cubic feet in 2012. Alberta consumed 44 per cent (1.7 trillion cubic feet) of its marketable natural gas, with the remaining 56 per cent (2.0 trillion cubic feet) being delivered to other Canadian provinces and the United States. ($1.3 B /yr) ***

In 2011, Alberta produced 490,000 barrels per day (bbl/d) of conventional light, medium and heavy crude (180×10^{6} bbl/yr) ($1.8 B /yr)

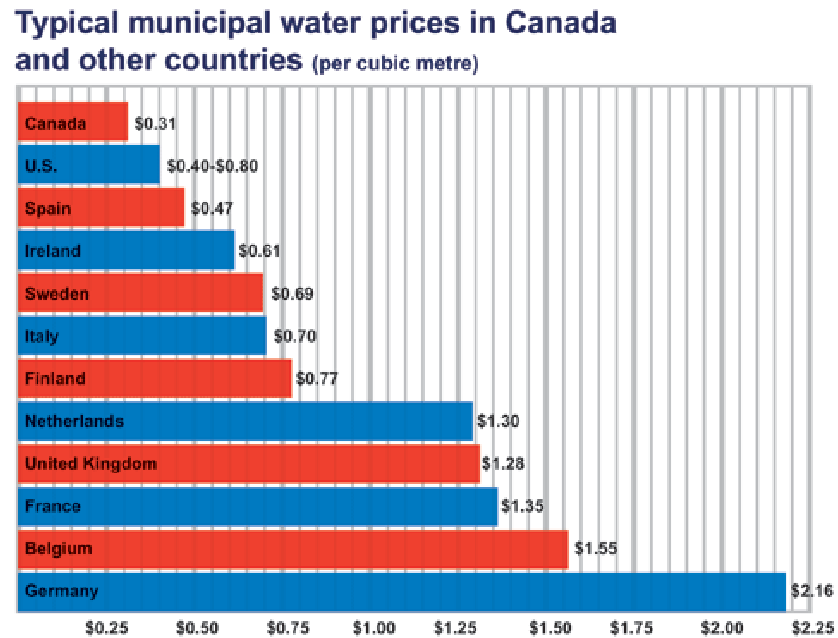
The average Albertan uses 350 liters (90-100 gallons) of water per day. (8 M bbl/d?????, really?) ($820 M /yr)

*** don't forget that the natural gas is transported at 650 to 1000 psi and these values are stated Standard conditions.

Production Statistics

Husky store:

1L – bottle of water = $1.00 to $6.00
1L – container of 5W-30 oil = $4.49



My house :

Monthly water bill = $175.00 TO $225.00
Natural gas = $300.00 TO $800.00
Electricity = $350.00 TO $800.00

mmmmm……

Legal requirements **and** flow measurement standards

$$$$ Fiscal Measurement or Custody Transfer – any *agreed* upon accuracy.

Pipeline or system operations, measurement variance, plant balance. Accuracy rears its ugly head.

Legal requirements and flow measurement standards

Oil and Gas

AEUB, or AUB (Alberta Energy Utilities Board)
ERCB
AUC (Alberta Utilities Commission)
AER (Alberta Energy Regulator is the latest, as of June 17, 2013)
Measurement Canada
BLM
BEOM (bureau of Ocean energy Management)

Water

Measurement Canada
Municipalities – Via standards
AER?

The **Energy and Utilities Board** (EUB) was the governing body of the energy industry in the province of Alberta, Canada. Previously known as the Alberta Energy and Utilities Board (AEUB), the EUB was reorganized on 1 January 2008 into two separate regulatory bodies:
the Energy Resources Conservation Board (ERCB), which regulates the oil and gas industry, and
the Alberta Utilities Commission (AUC), which regulates the utilities industry.

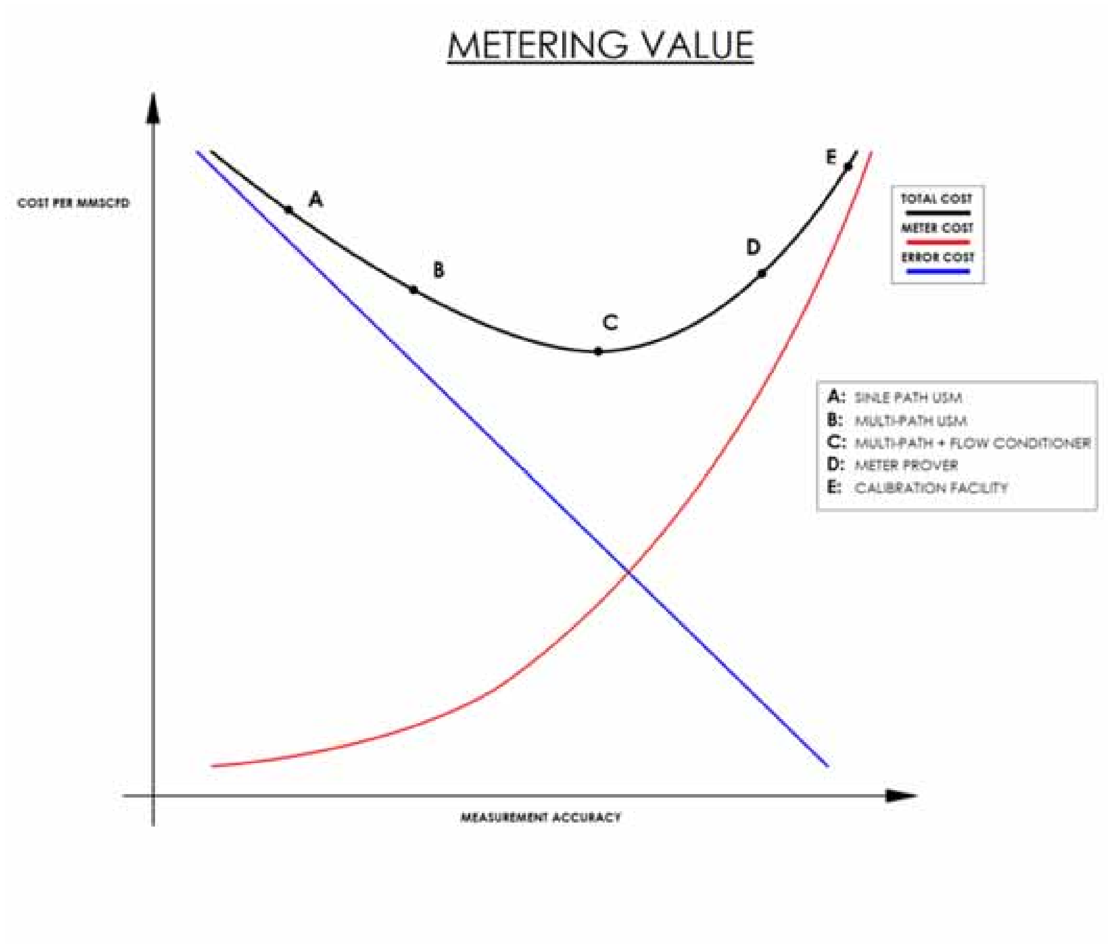
1995: The Alberta Energy and Utilities Board (EUB) was created
The Public Utilities Board and the Energy Resources and Conservation Board (previously the Petroleum and Natural Gas Conservation Board) merged to create the Alberta Energy and Utilities Board (EUB) in order to provide a more streamlined and efficient regulatory process.
(sited: Alberta Energy: Alberta Utilities Commission and the Energy Resources Conservation Board. http://www.auc.ab.ca/about-the-auc/who-we-are/Pages/History.aspx)

Legal requirements and flow measurement standards

Oil and Gas ***	Water
AGA	AWWA
API	ISO
ISO	ASME
ASME	ANSI
ANSI	

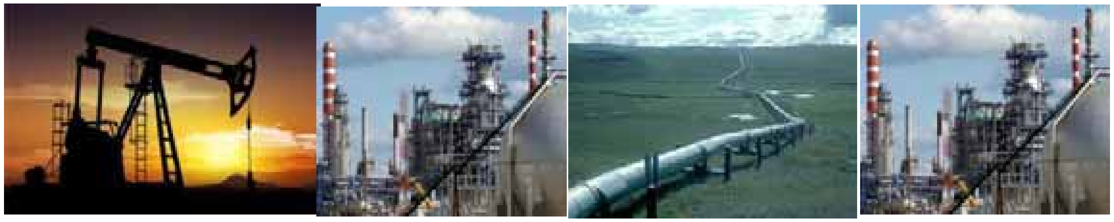
*** An accuracy value is not given, recommended, referenced, defined.

Legal requirements and flow measurement standards



Legal requirements and flow measurement standards

OIL



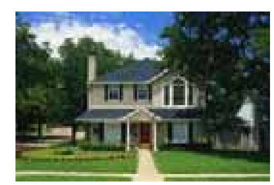
Uncertainty

5% → 0.3-0.4% → 0.3-0.4% → 0.3-0.4% →

AER, AEUB → Measurement Canada →

Jurisdiction

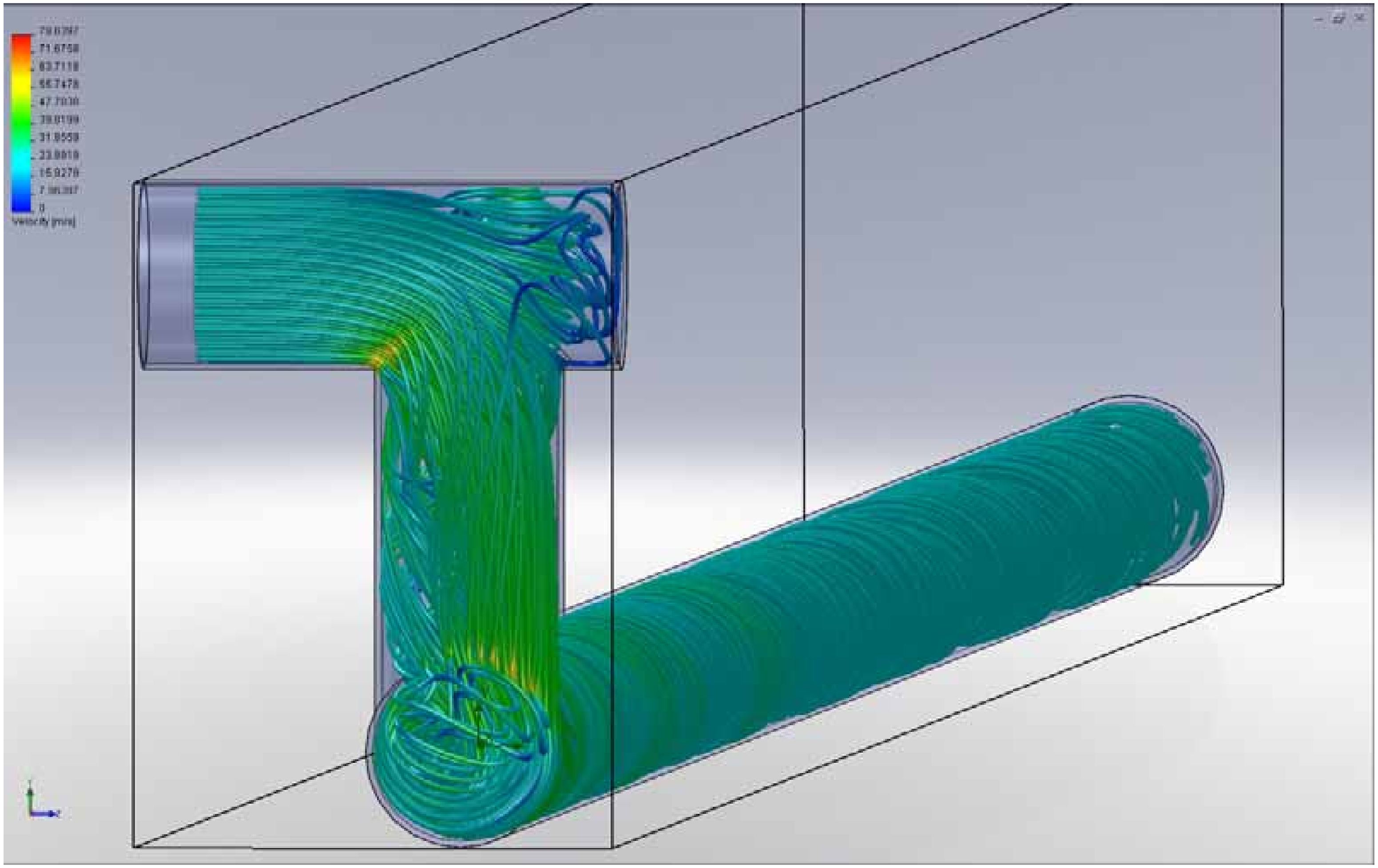
Natural Gas



Industry Association

- Appalachian Gas Measurement School
- International School of Hydrocarbon Measurement
- American School of Gas Measurement Technology
- Colorado Engineering and Experiment station seminars and schools – 4/yr
- Canadian School of Hydrocarbon Measurement
- American Gas Association – 3 to 4/yr
- American Petroleum Institute – 3 to 4/yr
- Western Gas Measurement – every second year
- Acadiana Flow Measurement School
- NEL Scotland
- NEL Kuala Lumpur, Singapore
- Canadian Gas Association
- Flomeko
- Symposium of Fluid Flow MEasurement

Measurement Uncertainty



Measurement Uncertainty

Two approaches:
1. Typical square root of the squares (RSS)

ANSI/ASME MFC2M-1983…

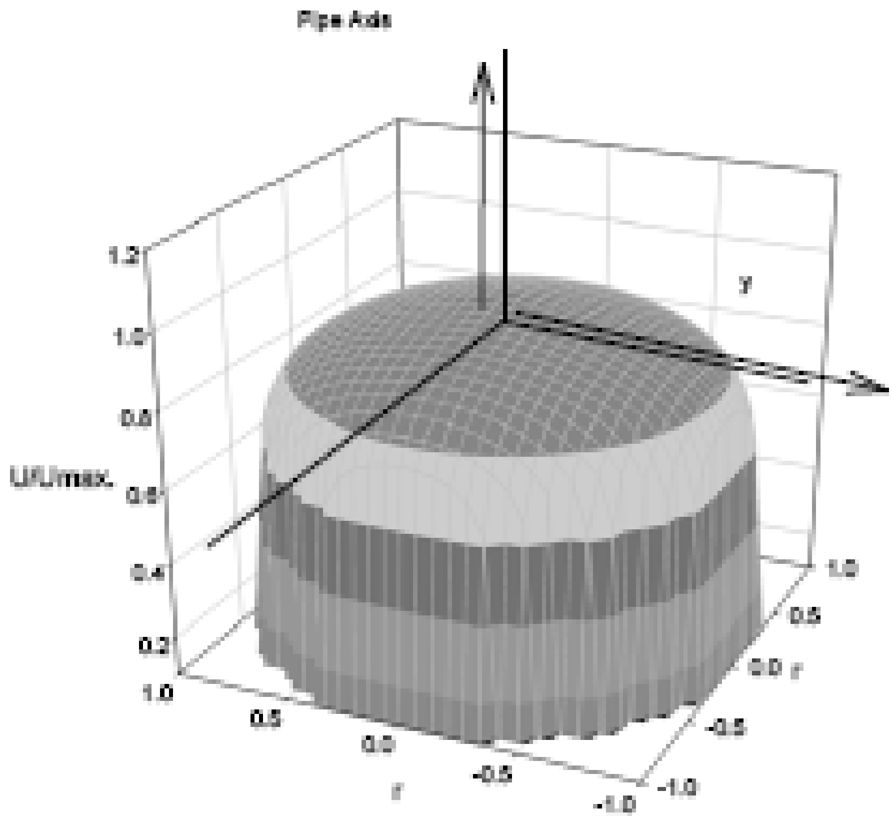
$$U_{RSS} = U_{95} = \pm\sqrt{\left((Bias^2) + (Systematic^2)\right)}$$

1. ISO

ISO 5168 (1978, 1989,…)
Correlated and uncorrelated terms
Not here not now…look it up….

$$U^2(y) = \sum_{i=1}^{n} c^2 u^2(x) + 2\sum_{i=1}^{n-1} * \sum_{j=i+1}^{n-1} * c_i c_j u(x_i) \ldots.$$

1 Major Bias Error



Plot of: $f(r) = [1-(x^2+y^2)^{1/2}]^{1/10} = U/U_{max.}$

$$\frac{U_y}{U_{max}} = \left(1 - \frac{y}{R}\right)^{\frac{1}{n}}$$

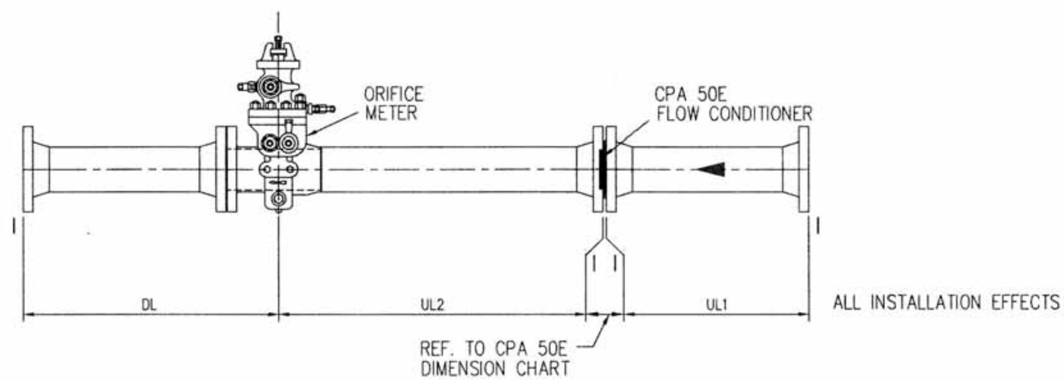
$$n = \frac{1}{\sqrt{f}},$$

Measurement Uncertainty

ORIFICE METER RUN LENGTHS – To the nearest Inch				
NPS	SCHEDULE	UL1 (5 Dia.)	UL2 (8 Dia.)	DL (5 Dia.)
2	40/80	10	16	10
4	40/80	20	32	20
6	40/80	30	48	30
8	40/STD.	40	64	40
8	80/XS	38	61	38
10	40/STD.	50	80	50
10	60/XS	49	78	49
10	80	48	76.5	48
12	STD.	60	96	60
12	40	60	95.5	60
12	XS	59	94	59
12	80	57	91	57
16	STD.	76	122	76
16	40/XS	75	120	75
16	80	71.5	114.5	71.5

20 and larger, Contact Canada Pipeline Accessories Co. Ltd. 1-888-FIX-FLOW

THESE DIMENSIONS ARE RECOMMENDED MINIMUM LENGTHS.
THIS DRAWING DOES NOT REPLACE THE STANDARD
THERE ARE OTHER REQUIREMENTS FOR A COMPLIANT METER RUN AND THE STANDARD MUST BE CAREFULLY FOLLOWED.



REVISIONS				
REV.	DATE	DESCRIPTION	BY	APP.
A	01-09-28	ISSUED FOR APPROVAL	RJ	

MATERIAL ____
UNMACHINED WEIGHT ____ lbs.
FINISHED SHIPPING WEIGHT ____ lbs.
CUSTOMER

CANADA PIPELINE ACCESSORIES

DESC. AGA-3/AP114.3 APRIL 2000 ORIFICE METER RUN

DRAWN	RELEASE DATE	DWG No.	REV.
R. Johnson	01-09-28	_____	A

ALL DIMENSIONS IN IMPERIAL-METRIC LAYER (4) TURNED OFF

ULTRASONIC METER RUN LENGTHS			
NPS	SCHEDULE	UL1 (5 Dia.)	UL2 (8 Dia.)
2	40/80	10	16
4	40/80	20	32
6	40/80	30	48
8	40/STD.	40	64
8	80/XS	38	61
10	40/STD.	50	80
10	60/XS	49	78
10	80	48	76.5
12	STD.	60	96
12	40	60	95.5
12	XS	59	94
12	80	57	91
16	STD.	76	122
16	40/XS	75	120
16	80	71.5	114.5

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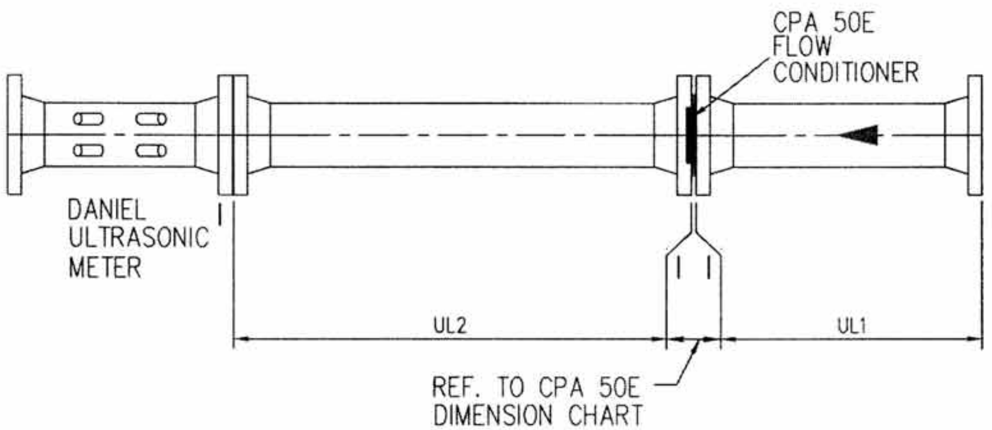


ALL INSTALLATION EFFECTS

REVISIONS				
REV.	DATE	DESCRIPTION	BY	APP.
A	01-09-28	ISSUED FOR APPROVAL	RJ	

MATERIAL ____

UNMACHINED WEIGHT ____ lbs.

FINISHED SHIPPING WEIGHT ____ lbs.

CUSTOMER

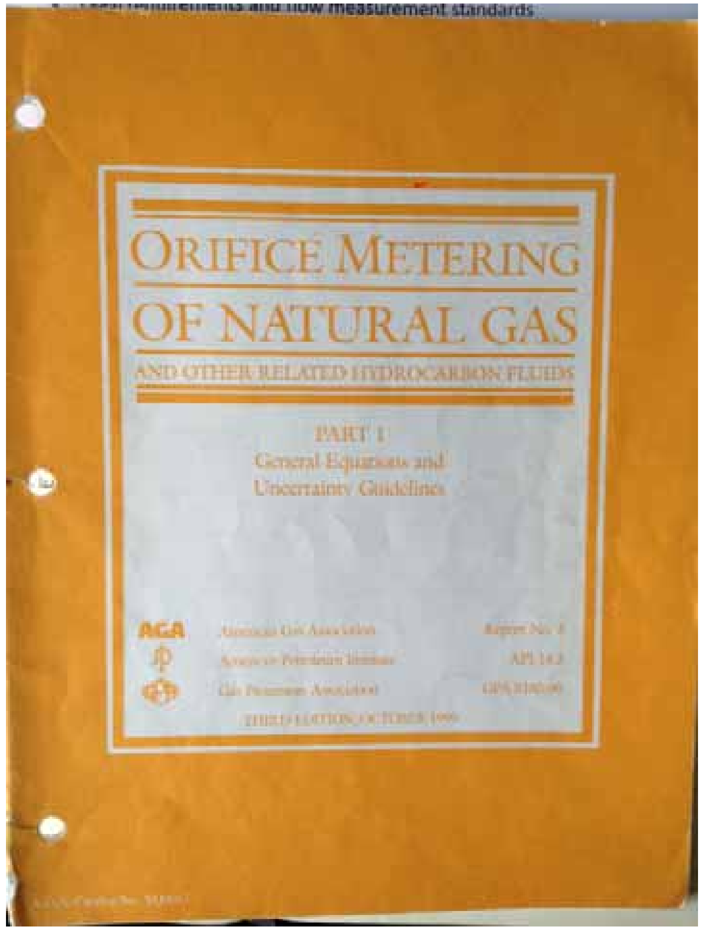
CANADA PIPELINE ACCESSORIES

DESC. DANIEL ULTRASONIC METER RUN SINGLE DIRECTION

DRAWN	RELEASE DATE	DWG No.	REV.
R. Johnson	01-09-28	____	A

ALL DIMENSIONS IN IMPERIAL-METRIC LAYER (4) TURNED OFF

Measurement Uncertainty



Measurement Uncertainty

rearrange:

$$q_m = \frac{C_d\, Y\, \frac{\pi}{4}\, d^2\, (2\rho\Delta P)^{1/2}}{(1-(\frac{d}{D})^4)^{1/2}}$$

giving: let $\epsilon_x = \frac{dx}{x}$

$$\epsilon_{q_m}^2 = \left(\frac{\partial q_m}{\partial C_d}\epsilon_{C_d}\right)^2 + \left(\frac{\partial q_m}{\partial Y}\epsilon_Y\right)^2 + \left(\frac{\partial q_m}{\partial d}\epsilon_d\right)^2 + \left(\frac{\partial q_m}{\partial D}\epsilon_D\right)^2 + \left(\frac{\partial q_m}{\partial \rho}\epsilon_\rho\right)^2 + \left(\frac{\partial q_m}{\partial \Delta P}\epsilon_{\Delta P}\right)^2$$

$$\frac{\partial q_m}{\partial C_d} = \frac{Y\, \frac{\pi}{4}\, d^2 (2\rho\Delta P)^{1/2}}{(1-(\frac{d}{D})^4)^{1/2}}$$

$$\frac{\partial q_m}{\partial Y} = \frac{C_d\, \frac{\pi}{4}\, d^2 (2\rho\Delta P)^{1/2}}{(1-(\frac{d}{D})^4)^{1/2}}$$

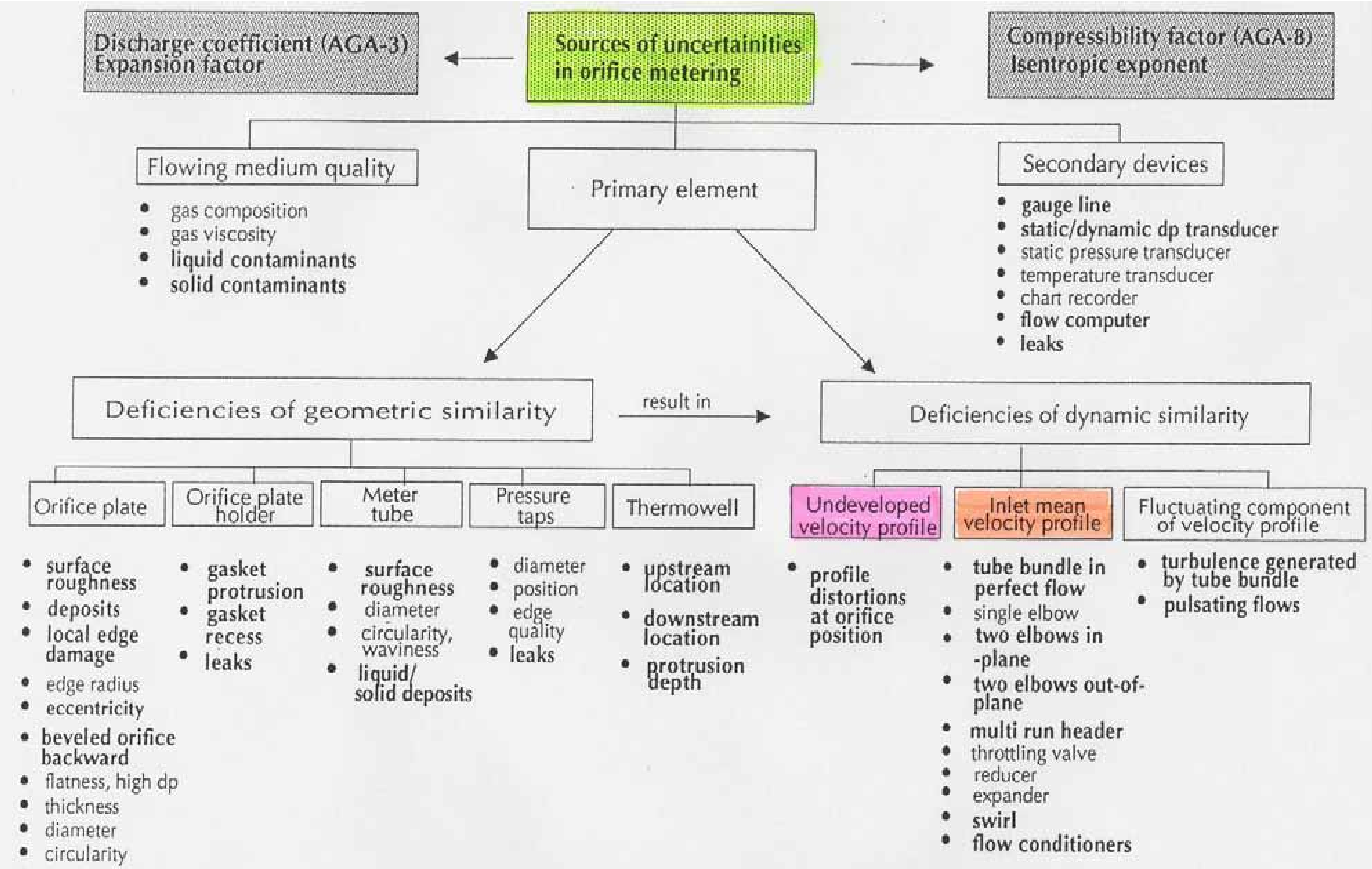
$$\frac{\partial q_m}{\partial d} = \frac{C_d\, Y\, \frac{\pi}{2}\, (2\rho\, \Delta P)^{1/2} d}{(1-(\frac{d}{D})^4)^{3/2}}$$

$$\frac{\partial q_m}{\partial D} = -\frac{(\frac{d}{D})^4 C_d\, Y\, \frac{\pi}{2}\, d\, (2\rho\Delta P)^{1/2}}{D\,(1-(\frac{d}{D})^4)^{3/2}}$$

$$\frac{\partial q_m}{\partial \rho} = \frac{C_d\, Y\, \frac{\pi}{8}\, d^2 (2\Delta P)^{1/2}\, \rho^{-1/2}}{(1-(\frac{d}{D})^4)^{1/2}}$$

$$\frac{\partial q_m}{\partial \Delta P} = \frac{C_d\, Y\, \frac{\pi}{8}\, d^2\, (2\rho)^{1/2}\, \Delta P^{-1/2}}{(1-(\frac{d}{D})^4)^{1/2}}$$

Orifice Uncertainty



Measurement Uncertainty

... gas application:

$$[\tfrac{1}{2}(\delta G_i/G_i)]^2 + [\tfrac{1}{2}(\delta P_f/P_f)]^2 + [-\tfrac{1}{2}(\delta Z_f/Z_f)]^2 + [-\tfrac{1}{2}(\delta T_f/T_f)]^2$$

An example of the effect of uncertainties is provided in Table 1-7, using the following gas flow equation:

$$q_m = C_d E_v Y(\pi/4)d^2 \sqrt{2g_c \frac{G_i Mr_{air} P_f}{Z_f R T_f} \Delta P} \qquad (1\text{-}45)$$

The following assumptions and conditions were selected for the calculation:

a. For each variable, the uncertainty listed represents random error only.
b. A 4-inch meter with a β ratio of 0.5 and static and differential pressures equal to 250 pounds per square inch absolute and 50 inches of water, respectively, was selected for the calculation.

Note: The precision of the ΔP device used in this example was ±0.25 percent of full scale.

Table 1-7—Example Uncertainty Estimate for Natural Gas Flow Calculation

		Uncertainty, U_{95} (%)	Sensitivity Coefficient, S	$(U_{95}S)^2$
C_d	Basic discharge coefficient (Figure 1-4)	0.44	1	0.1936
Y	Expansion factor (Table 1-5)	0.03	1	0.0009
d	Orifice diameter (Table 2-1)	0.05	$2/(1 - \beta^4)$	0.0114
D	Pipe diameter (2.5.1.3)	0.25	$-2\beta^4/(1 - \beta^4)$	0.0110
ΔP	Differential pressure	0.50	0.5	0.0625
P	Static pressure	0.50	0.5	0.0625
Z	Compressibility factor (A.G.A. 8)	0.1	–0.5	0.0025
T	Flowing temperature	0.25	–0.5	0.0156
G	Relative density	0.60	0.5	0.0900
Sum of squares				0.4500
Square root of sum of squares				0.6700

Note: As the table shows, the overall gas flow measurement uncertainty at a 95-percent confidence level is ±0.67 percent.

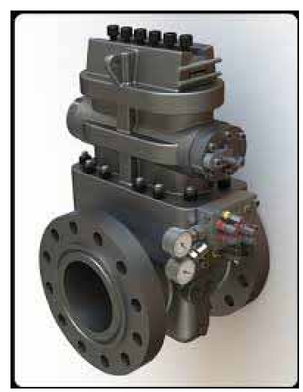
Measurement Uncertainty

Meter Uncertainty						
	Turbine	Ultrasonic	Coriolis	Orifice	Positive displacement	
Uncertainty analysis completed	Yes/No	Yes/No	No	Yes	NO	
% usage, by volume	5	45	5	45	.001	
% usage by # of locations	.5	10	1	90	1	

Meter Types

Meter Types						
	Turbine	Ultrasonic	Coriolis	Orifice	Positive displacement	
% usage, by volume	5	45	5	45	.001	
% usage by # of locations	.5	10	1	90	1	

USM origins are in the water works – next slide…



Types of Meters

Write this down

Some of "the best" reference papers on Ultrasonic Metering are Water works papers:

Acoustic time of flight measurement in the Penstock
P. Gruber, Rittmeyer Ltd. Switzerland – for B.C Hydro

Comparison of integration methods for multipath acoustic discharge measurements
Thomas Tresh HTA Lucerne, Peter Gruber, Thomas Staubli, HTA Lucernce
6th International conference on innovation in hydraulic efficiency measurements, July 30 2006, Portland

Presentation of optimized integration methods and weighting corrections for the acoustic discharge measurement
Thomas Tresch, Bruno Luscher, Thomas Staubli, Peter Gruber
IGHEM – International conference on hydraulic efficiency measurements, Sept 2008, Milano

Questions?

Meter specifics
Calibrations
Meter runs
QA